



# Human Exploration and Operations Mission Directorate (HEOMD)

*FY 2020 Budget Overview*

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# Human Exploration and Operations

## *Agenda*

- Overview
  - Artemis Program
  - FY 2020 Strategy/Budget Overview
  - FY 2018 Accomplishments
  - FY 2019 Work In Progress
- Programs
  - Exploration Research and Development
    - Advanced Cislunar and Surface Capabilities
    - Gateway
    - Advanced Exploration Systems
    - Human Research Program
  - Exploration Systems Development
    - Orion
    - Space Launch System
    - Exploration Ground Systems
  - International Space Station
  - Commercial LEO Development
  - Space Transportation
    - Crew and Cargo Program
    - Commercial Crew Program
  - Space and Flight Support
    - Space Communications and Navigation
    - Communication Services Program
    - Rocket Propulsion Testing
    - Launch Services Program
    - Human Space Flight Operations

# Supporting National Space Policy Directives



In keeping with SPD-1, NASA is charged with **landing the first American woman and next American man at the South Pole of the Moon by 2024, followed by a sustained presence on and around the Moon by 2028.**

NASA will **“use all means necessary”** to ensure mission success in moving us forward to the Moon.

# Why Go to the Moon?

Establishes American leadership and strategic presence

Proves technologies and capabilities for sending humans to Mars

Inspires a new generation and encourages careers in STEM

Leads civilization changing science and technology

Expands the U.S. global economic impact

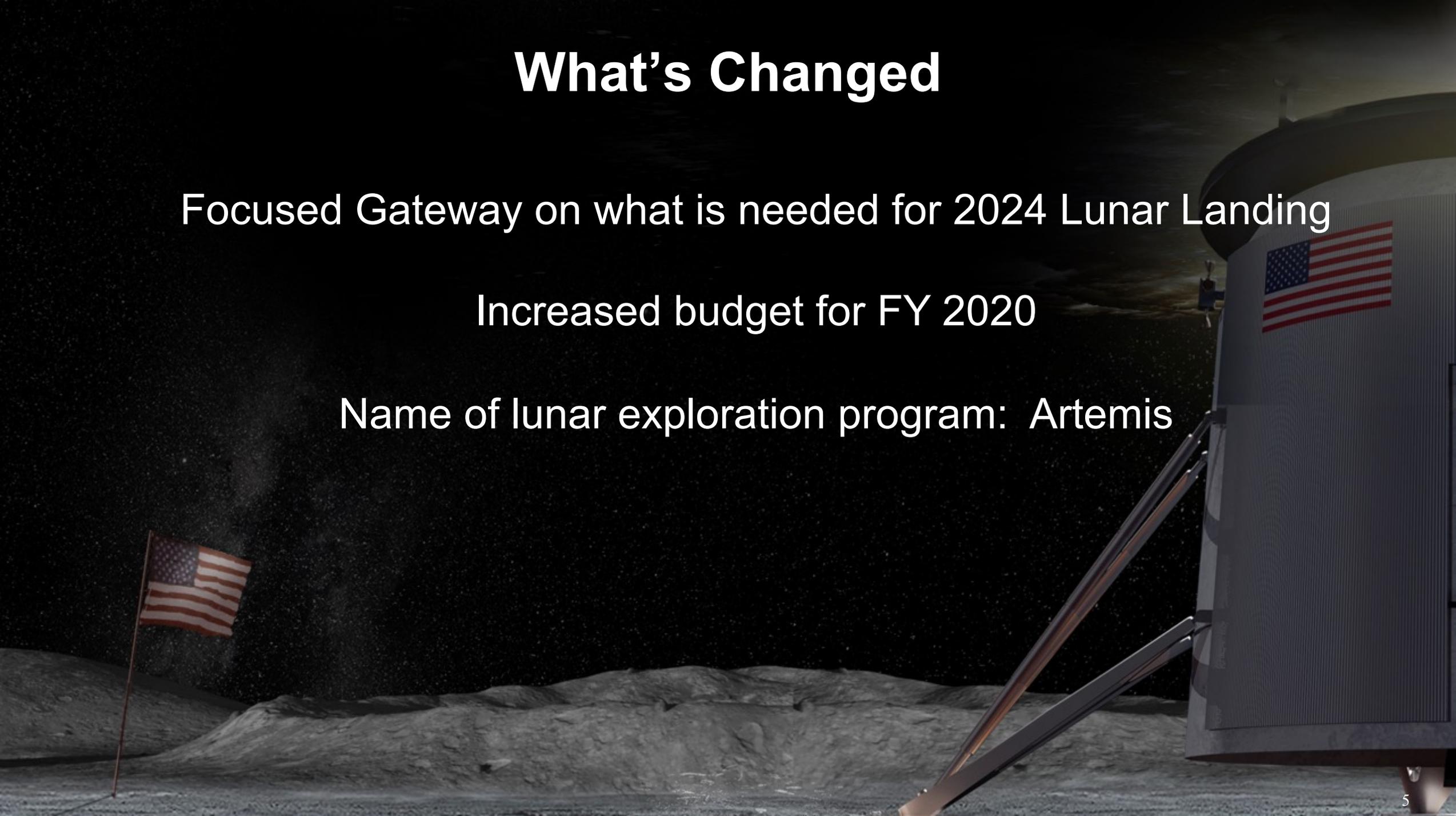
Broadens U.S. industry & international partnerships in deep space

# What's Changed

Focused Gateway on what is needed for 2024 Lunar Landing

Increased budget for FY 2020

Name of lunar exploration program: Artemis

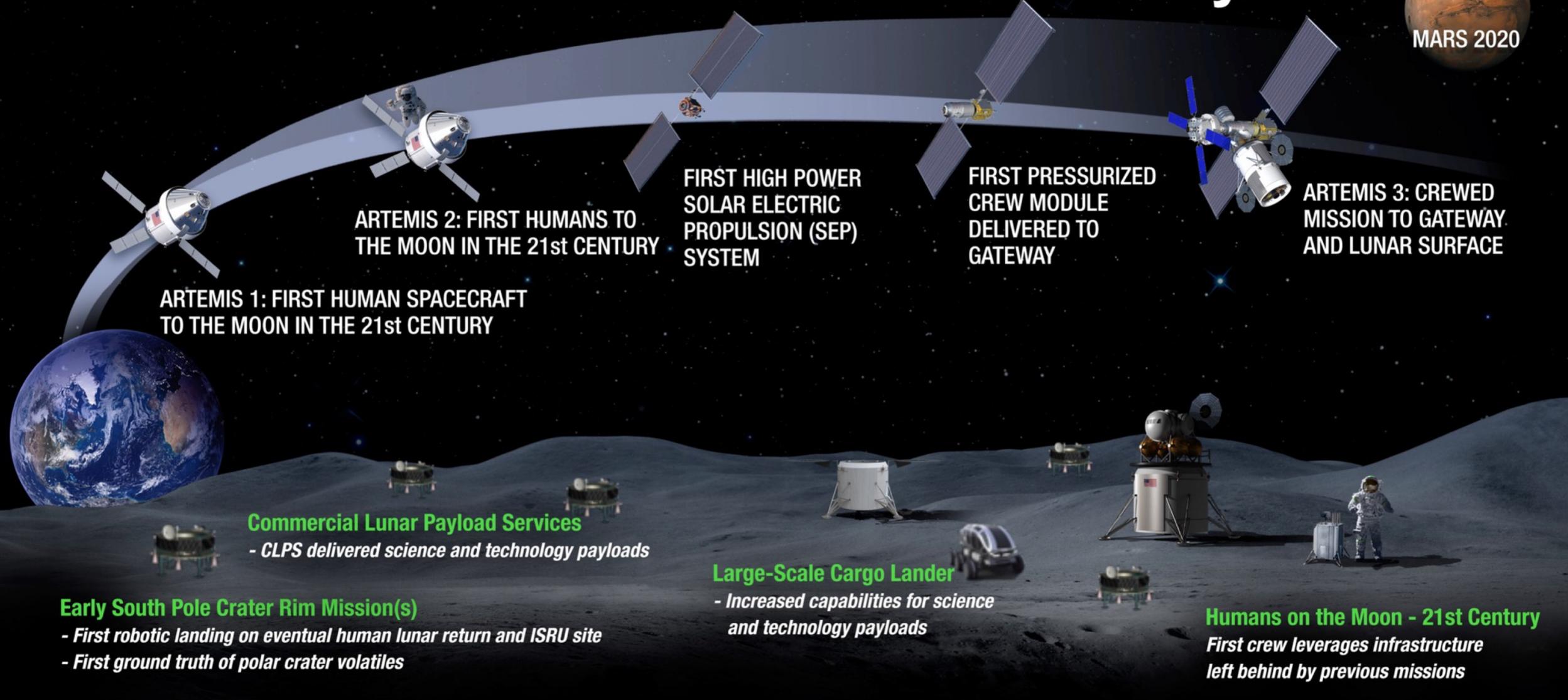


# A Budget Increase Towards 2024

- The FY2020 budget amendment provides an *increase* of **\$1.6 billion** above the president's initial **\$21 billion** budget request with no money taken from existing NASA programs. This is the *boost* NASA needs.
  - ✓ \$1 billion to accelerate development of human lunar transportation systems to take astronauts to the surface and back to Gateway\*
  - ✓ \$651 million towards the completion of SLS and Orion to support a 2024 landing.
  - \$132 million for new technologies to help astronauts live and work on the lunar surface and in deep space.
  - \$90 million for Science to increase robotic exploration at the lunar South Pole in advance of astronauts.

*\* Focusing Gateway on just the capabilities needed for Phase 1 allowed for a \$321M scope reduction and shifts potential development and expanded capabilities for Gateway into Phase 2.*

# Artemis Phase 1: To the Lunar Surface by 2024



ARTEMIS 1: FIRST HUMAN SPACECRAFT TO THE MOON IN THE 21st CENTURY

ARTEMIS 2: FIRST HUMANS TO THE MOON IN THE 21st CENTURY

FIRST HIGH POWER SOLAR ELECTRIC PROPULSION (SEP) SYSTEM

FIRST PRESSURIZED CREW MODULE DELIVERED TO GATEWAY

ARTEMIS 3: CREWED MISSION TO GATEWAY AND LUNAR SURFACE

**Commercial Lunar Payload Services**  
- CLPS delivered science and technology payloads

**Early South Pole Crater Rim Mission(s)**  
- First robotic landing on eventual human lunar return and ISRU site  
- First ground truth of polar crater volatiles

**Large-Scale Cargo Lander**  
- Increased capabilities for science and technology payloads

**Humans on the Moon - 21st Century**  
First crew leverages infrastructure left behind by previous missions

## LUNAR SOUTH POLE CRATER TARGET SITE

2019

2024



# Human Exploration and Operations

## *FY 2020 Budget Strategy/Overview*

FY 2020 budget submit provides approximately \$10.6B (not including Exploration Technology and Science Mission Directorate Lunar) to continue pursuit of Administration and NASA Exploration goals, consistent with National Space Policy Directives

- HEO's submit enables NASA's Artemis Program to put the first woman and return man to the surface of the Moon and to expand human presence back to the surface of the Moon and into the solar system, with robust capabilities that ensure flexibility in destination, affordability and sustainability
  - Supports significant collaboration with commercial partners and opportunities for international partners
  - Builds the space transportation system (Orion crew vehicle, SLS rocket and EGS Capabilities) that will enable missions to return to the Moon's surface for long-term exploration
- Uses innovative procurement approaches to accelerate Human Landing Systems (HLS) capabilities under Advanced Cislunar and Surface Capabilities (ACSC) that will, along with other Artemis activities, re-establish U.S. preeminence to, around, and on the surface of Moon, leading to a human landing by 2024
  - Integral part of Artemis with Science Mission Directorate (SMD) and Exploration Technology, ACSC develops the capability to systematically evolve into long-term human exploration and utilization on the Moon



# Human Exploration and Operations

*FY 2020 Budget Strategy/Overview (continued)*

- Continues development of Gateway as part of Artemis serving as a critical staging point to enable reusability and robust access by landers to the surface of the Moon
  - Gateway shall be utilized to enable a whole-Moon approach to exploration that will make it possible to achieve multiple objectives for both science and human exploration from a critical exploration platform
  - Focused Gateway initially on what is needed for 2024 Lunar Landing
    - Development of an advanced Power and Propulsion Element (PPE) and minimum habitation capability
- Develop other capabilities required for future deep space missions
  - Researches human health and performance to understand how crew can travel and live safely away from Earth for long durations
  - Develops habitation capabilities and habitation systems that will reduce operational risk and lifecycle costs and implement a phased approach to advance habitation systems development
    - Partners with commercial industry to develop prototype habitats, life support systems and other habitation technologies ready to feed forward and conduct integrated ground testing; continues ISS-based testing to reduce risk for deep space missions



# Human Exploration and Operations

*FY 2020 Budget Strategy/Overview (continued)*

- Utilizes ISS to prepare for human deep space exploration, conduct research and technology development and enable commercialization
- Promotes economic growth, encourages American leadership in space commerce and reduces current reliance on foreign providers
  - Makes multiple selections in FY 2019 and early FY 2020 for partnerships with industry to develop commercial LEO destinations located at the ISS N2 forward port and as free-flying platforms
  - Supports port accommodations on ISS
  - Expand ISS commercial use policy and enable Private Astronaut Missions to ISS
  - Supports Commercial Cargo Resupply Service (CRS) contracts with three providers and commercial crew transportation contracts with two providers
  - Establish new Communication Services Program to begin purchasing commercially-provided satellite-based data relaying services
- Provides critical communication, navigation, launch, rocket propulsion testing and other services to NASA, external customers, and partners



# Human Exploration and Operations

## FY 2020 Program Financial Plan

	FY 2019 Enacted	PBR	Budget Amendment	Delta	FY 2020 Request			
<i>Budget Authority (\$ in millions)</i>	*2019	2020	2020		2021	2022	2023	2024
<b>Human Exploration and Operations</b>	<b>9,689.9</b>	<b>9,307.4</b>	<b>10,682.1</b>	<b>1,374.7</b>	<b>9,665.0</b>	<b>9,850.9</b>	<b>10,874.5</b>	<b>11,224.6</b>
<b>Deep Space Exploration Systems</b>	<b>5,050.8</b>	<b>5,021.7</b>	<b>6,396.4</b>	<b>1,374.7</b>	<b>5,295.5</b>	<b>5,481.4</b>	<b>6,639.0</b>	<b>7,042.3</b>
<b>Exploration Systems Development</b>	<b>4,092.8</b>	<b>3,441.7</b>	<b>4,092.7</b>	<b>651.0</b>	<b>3,441.0</b>	<b>3,468.4</b>	<b>3,788.5</b>	<b>3,654.7</b>
Orion Program	1,350.0	1,266.2	1,406.7	140.5	1,245.7	1,146.7	1,119.3	1,000.0
Space Launch System	2,150.0	1,775.4	2,285.9	510.5	1,837.5	1,933.0	2,221.2	2,253.3
Exploration Ground Systems	592.8	400.1	400.1	-	357.8	388.7	448.1	401.3
<b>Exploration Research and Development</b>	<b>958.0</b>	<b>1,580.0</b>	<b>2,303.7</b>	<b>723.7</b>	<b>1,854.5</b>	<b>2,013.0</b>	<b>2,850.4</b>	<b>3,387.6</b>
Adv Cislunar and Surface Capabilities	116.5	363.0	1,407.8	1,044.8	647.0	967.7	1,775.9	2,360.0
Gateway	450.0	821.4	500.3	(321.1)	827.7	717.0	787.8	757.5
<i>Power and Propulsion Element</i>	-	175.4	175.4	-	151.0	91.5	18.7	2.1
<i>Habitation</i>	176.2	614.1	614.1	-	624.7	527.5	647.6	681.0
<i>Airlock</i>	-	2.0	2.0	-	2.0	23.0	29.0	45.0
<i>Logistics</i>	-	30.0	30.0	-	50.0	75.0	92.5	29.3
Advanced Exploration Systems	-	255.6	255.6	-	239.8	188.3	146.7	130.1
Human Research Program	145.0	140.0	140.0	-	140.0	140.0	140.0	140.0
<b>LEO and Spaceflight Operations</b>	<b>4,639.1</b>	<b>4,285.7</b>	<b>4,285.7</b>	<b>-</b>	<b>4,369.5</b>	<b>4,369.5</b>	<b>4,235.5</b>	<b>4,182.3</b>
<b>International Space Station</b>	<b>-</b>	<b>1,458.2</b>	<b>1,458.2</b>	<b>-</b>	<b>1,448.5</b>	<b>1,449.4</b>	<b>1,425.1</b>	<b>1,412.6</b>
<b>Space Transportation</b>	<b>-</b>	<b>1,828.6</b>	<b>1,828.6</b>	<b>-</b>	<b>1,854.1</b>	<b>1,814.5</b>	<b>1,673.7</b>	<b>1,630.3</b>
Commercial Crew Program	-	102.0	102.0	-	64.5	63.2	63.2	64.6
Crew and Cargo Program	-	1,726.6	1,726.6	-	1,789.6	1,751.2	1,610.5	1,565.7
<b>Space and Flight Support</b>	<b>-</b>	<b>848.9</b>	<b>848.9</b>	<b>-</b>	<b>891.9</b>	<b>905.7</b>	<b>911.8</b>	<b>914.5</b>
21st Century Space Launch Complex	15.0	-	-	-	-	-	-	-
Space Communications and Navigation	-	611.0	611.0	-	632.4	593.0	562.9	557.0
Communication Services Program	-	3.0	3.0	-	23.4	67.0	101.2	108.9
Human Space Flight Operations	-	99.8	99.8	-	99.9	109.5	111.4	112.4
Launch Services	-	88.6	88.6	-	88.6	88.6	88.6	88.6
Rocket Propulsion Test	60.0	46.5	46.5	-	47.6	47.6	47.6	47.6
<b>Commercial LEO Development</b>	<b>40.0</b>	<b>150.0</b>	<b>150.0</b>	<b>-</b>	<b>175.0</b>	<b>200.0</b>	<b>225.0</b>	<b>225.0</b>
<b>Construction and Environment Compliance</b>	<b>44.8</b>	<b>71.6</b>	<b>71.6</b>	<b>0.0</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>
<b>Deep Space Exploration Systems</b>	<b>25.9</b>	<b>52.1</b>	<b>52.1</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>
Orion	-	2.5	2.5	-	-	-	-	-
Space Launch System	8.4	17.2	17.2	-	-	-	-	-
Exploration Ground Systems	17.5	32.4	32.4	-	-	-	-	-
<b>LEO and Spaceflight Operations</b>	<b>18.9</b>	<b>19.5</b>	<b>19.5</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>
Rocket Propulsion Test	-	1.1	1.1	-	-	-	-	-
Space Communications and Navigation	16.9	18.4	18.4	-	-	-	-	-
Launch Services	2.0	-	-	-	-	-	-	-



# Human Exploration and Operations

## *FY 2018 Achievements*

- Developed Exploration vehicles and capabilities to return American Astronauts to the Moon and extend human presence into the solar system
  - Completed fabrication by additive manufacturing of key components for Lunar CATALYST partners
  - Completed industry studies and released solicitation through a BAA for partnerships for Power and Propulsion Element (PPE), the foundational element for Gateway
  - Released several requests for information (RFI) regarding utilization of science, technology and commercial entities for use on Gateway, as well as emerging commercial surface capabilities to enable regular access to the lunar surface
  - Continued to develop prototype cislunar habitats which will create a diverse set of complete, long duration deep space architecture designs
  - Began acceleration of deep space life support systems for demonstration and testing on ISS
  - Conducted Agency level Gateway Acquisition Strategy Meeting
  - Conducted Gateway Formulation Sync Review kickoff, equivalent of program-level Systems Requirements Review
  - Completed Artemis-1 Orion Crew Module initial power-on
  - Delivered Artemis-2 Orion Pressure Vessel to KSC from MAF
  - Completed all 10 Artemis-1 solid rocket booster sections and began casting Artemis-2 solid rocket booster sections
  - Completed Launch Vehicle Stage Adapter (LVSA) and shipped Orion Stage Adapter (OSA) to KSC
  - Transported the Mobile Launcher atop Crawler Transporter 2 to Launch Pad 39B to undergo a fit check and systems testing followed by a second move into the Vehicle Assembly Building (VAB) for additional testing



# Human Exploration and Operations

*FY 2018 Achievements (continued)*

- Advanced U.S. commercial space transportation and enabled aerospace industry to encourage American leadership in space commerce and promoted economic growth
  - Conducted five Commercial Resupply Service (CRS) cargo missions
  - Made tangible progress toward Commercial Crew Program (CCP) flight tests and crewed missions to ISS
  - Selected astronauts for first crewed CCP test flights and Post Certification Missions
- Continued U.S. Human Spaceflight leadership through ISS International Partnership and Commercialization
  - Conducted eight U.S. Orbital Segment (USOS) Extravehicular Activities (EVAs) and two Russian EVAs
  - Selected 12 companies to study the future of commercial human spaceflight in low Earth orbit, including long-range opportunities for ISS
  - Performed hundreds of investigations on ISS to inform exploration and scientific discovery
  - Supported 24/7 ISS mission operations



# Human Exploration and Operations

*FY 2018 Achievements (continued)*

- Provided effective space communications, launch services, rocket propulsion testing and human spaceflight support services to NASA programs, external customers and partners
  - Initiated first research selections under the Translational Research Institute for Space Health
  - Provided propulsion test data to SLS and Orion in support of Artemis-1 and Artemis-2
  - Continued improvements to future space exploration propulsion needs through the Rocket Propulsion Testing activities
  - Launched Transiting Exoplanet Survey Satellite (TESS), Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight), Parker Solar Probe and Ice, Clouds and land Elevation Satellite (ICESat-2)
  - Provided training requirements and mission operations support for first commercial test flights of NASA crewed SpaceX Dragon and Boeing Starliner commercial spacecraft
  - Certified astronauts for both long and short duration spaceflight missions in support of ISS and Commercial Crew Programs, including the Non NASA (Boeing) Crewmember



# Human Exploration and Operations

*FY 2019 Work in Progress*

- Develop Exploration vehicles and capabilities to return American Astronauts to the Moon and to extend human presence into the solar system
  - Complete lunar landing systems architecture by the end of the fiscal year
    - 11 companies selected to begin work for NextSTEP BAA Appendix E – Descent Element, Transfer Element, and Refueling studies and prototypes
      - Feedback from Appendix E companies will inform Appendix H
    - NextSTEP Appendix H solicitation for development, integration, and crewed demonstration of integrated landing system will be released NET July
    - Surface Suit: Initial Capability Suit will mitigate schedule and mass risk in order meet 2024 mission timeline
  - Complete Lunar CATALYST partnerships
  - Selected Maxar Technologies as industry partner-for Gateway PPE
  - Establish acquisition strategy decisions and initiate acquisitions for Gateway minimum habitation module and logistics elements
  - Complete mating and stacking of Crew Module (CM) and Service Module (SM) for Artemis-1
  - Complete final assembly for Ascent Abort (AA)-2 and conduct the launch abort test
  - Complete Intertank Structural Test Articles (STA) testing
  - Complete delivery of all STAs to MSFC for testing
  - Award in June construction contract for new second Mobile Launcher utilizing Congressionally mandated funding
  - Negotiate and sign Orion Production and Operations Contract that assures an affordable and sustainable program to support Artemis
  - Continue procurement and development of ICPS and Fairing in support of Europa Clipper mission utilizing Congressionally mandated funding



# Human Exploration and Operations

*FY 2019 Work in Progress (continued)*

- Continue procurement efforts to separate SLS Stages prime contract hardware deliverables (CS-1, CS-2, EUS) into a revised contract structure to improve cost and schedule performance insight
- Continue SE&I analysis, MAF and SSC facility investments, Universal Stage Adaptor and Payload Adaptor development, and design work on a more optimized EUS to meet minimum co-manifested payload requirements utilizing Congressionally mandated EUS funding
- ISS partners issued a Joint Statement on March 5, 2019 acknowledging the lunar Gateway as a critical next step supporting sustainable human and robotic access to the lunar surface and building invaluable experience needed for the challenges of later human missions to Mars
- Advance U.S. commercial space transportation and enable aerospace industry to advance American leadership in space commerce and promote economic growth
- Complete five CRS cargo flights and continue to make progress on CRS-2 integration milestones
- Successfully completed SpaceX Demo-1 (uncrewed test flight); SpaceX Demo-2 (crewed test flight) and Boeing flight tests are planned
- Continue U.S. Human Spaceflight leadership through ISS International Partnership and Commercialization efforts
  - Conduct and enable exploration research and technology development
  - Advance benefits to humanity, including economic development, through government and private industry research



# Human Exploration and Operations

*FY 2019 Work in Progress (continued)*

- Release solicitations for development of Commercial LEO destinations
- Expand ISS commercial use policy
- Foster demand and market development for commercial activities in LEO
- Conduct six USOS EVAs and two Russian EVA's
- Provide effective space communications, launch services, rocket propulsion testing and human spaceflight support services to NASA programs
  - Provide continued operations and upgrades to Space Network, Deep Space Network and Near Earth Network
  - Completed SGSS Systems Acceptance Test in preparation for the Initial Operations Readiness Review
  - Continue technology development and partnerships to evolve future capabilities for NASA exploration and science, such as optical and quantum communications
  - Conduct mission design and launch integration support to 60 missions in various stages of development, including supporting the plan for commercial logistics services for Gateway
  - Successful Venture Class demonstration launch by Rocket Lab December 2018
  - Support flight crew training requirements and operate program support aircraft
  - Provide preventive and primary health care for current astronauts and maintain a robust long term health monitoring program for former astronauts



# Human Exploration and Operations

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## Exploration Research and Development

*Advanced Cislunar and Surface Capabilities*

*Gateway*

*Advanced Exploration Systems*

*Human Research Program*



# Human Exploration and Operations

## *Advanced Cislunar and Surface Capabilities: FY 2020 Program Review*

<b>(\$M)</b>	<b>2019 *</b>	<b>2020**</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>	<b>2024</b>
<b>FY 2020 PBR</b>	<b>\$116.5</b>	<b>\$1,407.8</b>	<b>\$647.0</b>	<b>\$967.7</b>	<b>\$1,775.9</b>	<b>\$2,360.0</b>

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

*\*\*2020 column reflects adjustment for Agency Budget Amendment*

- Program Plans for FY 2020

- Accelerates development of a human lunar landing architecture that will include a crewed mission by 2024 to return humans to the lunar surface
  - The program will focus on working with industry to create an affordable and sustainable capability
- Evolve lunar landing capabilities with an emphasis on a HLS capabilities
  - Begin development of FY 2024 HLS sized for the largest commercial launch vehicle available in FY 2024
  - Contract with at least two industry lander partners on lunar architecture for 2024 human return to the lunar surface
  - SRR for HLS
  - Develop plan for surface suit development



*Through the Advanced Cislunar and Surface Capabilities Program, NASA will return humans to the Lunar Surface*



# Human Exploration and Operations

## *Advanced Cislunar and Surface Capabilities: FY 2020 Program Review (continued)*

- Partner with SMD and Exploration Technology on CLPS, Tipping Point awards and technology development for related lander and surface systems
  - Continue ShadowCam instrument development for 2020 Korea Pathfinder Lunar Orbiter launch, as well as other lunar risk reduction activities
  - Outyear funding for the ACSC is not finalized
- 
- Major Changes in FY 2020
    - No longer pursuing FY 2022 planned 500kg payload and lander; SMD is requesting additional funding to potentially buy commercial services in this size range



# Human Exploration and Operations

*Gateway: FY 2020 Program Review*

<b>(\$M)</b>	<b>2019 *</b>	<b>2020**</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>	<b>2024</b>
<b>FY 2020 PBR</b>	<b>\$450.0</b>	<b>\$500.3</b>	<b>\$827.7</b>	<b>\$717.0</b>	<b>\$787.8</b>	<b>\$757.5</b>

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*\*\*2020 column reflects adjustment for Agency Budget Amendment*

- Program Plans for FY 2020

- Continue refinements to the Gateway implementation strategy, focusing on maintaining a lean approach to final configuration dependent upon international/domestic partnerships
- PPE, in conjunction with industry partner(s), will complete preliminary design phase
  - Milestones will include design reviews and procuring long lead items
  - PPE launch readiness no earlier than 2022 on a partner-provided commercial launch vehicle
- Initiate development acquisition for U.S. minimum habitation module of Gateway
- Outyear funding for the Gateway is not finalized



# Human Exploration and Operations

## *Gateway: FY 2020 Program Review (continued)*

- Gateway Elements will launch on commercial launch vehicles as part of their acquisitions
- Major Changes in FY 2020
  - Refinements were made for the Gateway implementation strategy
    - Focused Gateway on supporting 2024 Lunar Landing
    - Gateway Elements will launch on CLVs, which should reduce costs and accelerate timelines
    - Includes addition of NASA Docking System for the early elements of Gateway
    - Establishes the JSC Gateway Program Office



# Human Exploration and Operations

## *Advanced Exploration Systems: FY 2020 Program Review*

(\$M)	2019 *	2020	2021	2022	2023	2024
<b>FY 2020 PBR</b>		<b>\$255.6</b>	<b>\$239.8</b>	<b>\$188.3</b>	<b>\$146.7</b>	<b>\$130.1</b>

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- Program Plans for FY 2020

- Continue to deliver fundamental capabilities to provide astronauts a place to live and work with integrated life support systems, radiation protection, fire safety, avionics and software, logistics management and systems to manage waste
  - Launch and operate Saffire-IV while continuing development of Saffire-V and VI spacecraft fire safety experiments to demonstrate combustion products monitoring and post fire cleanup
  - Radiation sensors will be available to fly on Artemis-1
- Integrate CubeSat payloads for launch readiness on Artemis-1
  - Study the effects of deep space radiation on yeast DNA with BioSentinel
  - Visit a candidate asteroid for future human exploration using a solar sail through NEA Scout
  - Prospect for water in its various forms by scanning the lunar surface with Lunar IceCube
  - Capture and downlink infrared images of the lunar surface with the LunIR satellite



*Thermal Amine CO<sub>2</sub> Scrubber*



# Human Exploration and Operations

## *Advanced Exploration Systems: FY 2020 Program Review (continued)*

- Program Plans for FY 2020 (continued)
  - Demonstrate prototype systems and sub-systems on ISS including a brine processor to recover water from urine, a miniaturized spacecraft atmospheric monitor to detect both major and trace constituents in the air and a universal waste management system (UWMS toilet)
    - Operate early demonstrations on ISS
      - Mini CO<sub>2</sub> scrubber launched to ISS (second of 3 CO<sub>2</sub> removal system demonstrations) (NG-11)
      - RFID-Enabled Automated Logistics Management -2 (REALM-2) (NG-11)
      - Atmospheric siloxane control Filters (NG-11 & SpX-17)
      - Spacesuit Evaporation Rejection Flight Experiment and Spacecraft Atmosphere Monitor (SpX-18)
      - Spacecraft Fire Safety (Saffire - IV): (NG-12)
      - Spacecraft Fire Safety (Saffire-V: (NG-13)
      - Spacecraft Atmosphere Monitor (SpX-18)
      - UWMS – (NG-13 or SpX-21)
      - Water Capture Device for humidity control (SpX-19 and SpX-20)
      - Brine Processing Assembly and Upgraded Urine Processor Distillation Assembly – (SpX-21)
    - Continue flight hardware development projects for future ISS Demonstrations
- Major Changes in FY 2020
  - None



# Human Exploration and Operations

## Human Research Program: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
FY 2020 PBR	\$145.0	\$140.0	\$140.0	\$140.0	\$140.0	\$140.0

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

- Program Plans for FY 2020

- Support ISS testing of Advanced Twin Lifting and Aerobic System exercise device
- Coordinate with Gateway on future human test objectives to validate exercise, medical systems, and in-situ analysis capabilities
- Continue research on behavioral effects associated isolation and spaceflight associated neuro-ocular syndrome (SANS) with international partners using analog facilities
- Continue leveraging resources through collaborative research with other NASA programs, international partners and other U.S. agencies such as DoD, DOE, NSF, and NIH
- Continue biomedical research solicitations in partnership with Translational Research Institute for Space Health
- Undertake new risk mitigation research efforts
  - Implement microbial risk assessment study to ensure crew safety and allow increased dependence on bioregenerative food systems
  - Develop space habitat standards and evaluation tools for use in designing and evaluating volume and layout to optimize crew performance and health
  - Select new studies to better understand potential effects of space radiation on performance and initiate pharmaceutical studies to assess mitigation potential against the untoward effects of space radiation exposure



# Human Exploration and Operations

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## Exploration System Development

*Orion*

*Space Launch System*

*Exploration Ground Systems*



# Human Exploration and Operations

## *Exploration Systems Development: Budget Strategy*

- Develop foundational capabilities for human exploration required to explore and pioneer human presence into our solar system
- Assure integration of technical, schedule, and cost for all ESD programs (Orion/SLS/EGS) to prepare Artemis-1 and Artemis-2 missions and maintain rhythm of major progress indicators such as deliveries, tests, and flights
- NASA will focus on the successful completion of Artemis-1 and Artemis-2
  - Artemis-1 and Artemis-2 launch dates are under review pending completion of independent assessments of Artemis-1 schedule and core stage production due to delays in SLS core stage manufacturing and delivery
  - NASA leadership will review the results of these assessments in spring 2019 before considering potential updates to the launch planning dates
- ESD continues to progress on Artemis-1 and Artemis-2 while schedules are reassessed
  - Orion's Artemis-1 Assembly Test and Launch Operations schedule keeping steady pace since ESM was delivered to KSC last year
  - EGS's software and ground facilities are maintaining early completions to support Artemis-1 as soon as possible; optimizing integration timeline to accommodate anticipated Core Stage delivery
  - With the exception of Core Stage-1 challenges, other SLS elements are on pace to support new Artemis-1 launch dates with margin
  - Production of Artemis-2 hardware continues across the enterprise; subsequent builds will benefit from the lessons learned on Artemis-1



# Human Exploration and Operations

## *Exploration Systems Development: Budget Strategy (continued)*

- NASA will defer the SLS Block 1B configuration (with EUS)
  - NASA will use a Block 1 configuration with a human-rated ICPS
  - While NASA does not have a use for the second Mobile Launcher within the decade, to be consistent with current law, construction of the core elements for ML-2 will commence with a design and construction contract award in 2019
- NASA will assess mission planning to determine optimal launch times for crewed Orion relative to Gateway Elements launched on commercial providers to account for differences in transit times to reach NRHO



# Human Exploration and Operations

## Orion: FY 2020 Program Review

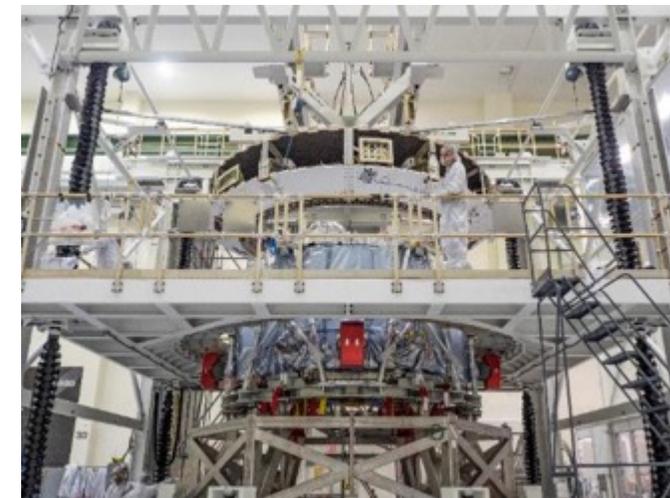
(\$M)	2019 *	2020**	2021	2022	2023	2024
FY 2020 PBR	\$1,350.0	\$1,406.7	\$1,245.7	\$1,146.7	\$1,119.3	\$1,000.0

\*2019 column reflects Enacted, will be updated pending Operating Plan approval

\*\*2020 column reflects adjustment for Agency Budget Amendment

- Program Plans for FY 2020

- Complete Artemis-1 Integrated Test Lab testing and begin Artemis-2 activities
- Complete STA testing required for Artemis-1
- Deliver mated Orion to Ground Operations for commodity servicing and final stacking in the VAB for Artemis-1 launch
- Complete Artemis-2 secondary structure, component assembly and heatshield
- Conduct Artemis-2 CM initial power-on testing
- Complete production of Artemis-2 Crew Module Adapter (CMA) and perform proof pressure, leak, harness and Developmental Flight Instrumentation tests
- Start development of rendezvous and docking capability to support Gateway, lunar orbit and surface activities
- Start Artemis-3 production and initiate long lead material purchases for Artemis-4 and Artemis-5



Artemis-1 ESM being mated with CMA immediately after arrival at KSC



Orion Structural Test Article



# Human Exploration and Operations

## Orion: FY 2020 Program Review (continued)

- Major Changes in FY 2020

- Develop rendezvous and docking capability for Gateway and surface support
- Accelerate purchase of core avionics shipset for Artemis-3, for use on Artemis-2
- Requirements maturity (P&O contract, ESM Parts, Mission Support Packages)
- Redesign new valves to meet safety requirements for Mark (MK) II

(Artemis 3 and 4)



*Astronauts training for Artemis-2 at the Neutral Buoyancy*



*O&C at KSC where technicians are assembling Orion Spacecraft for Artemis-1 and Artemis-2*



*Final Stir Friction Weld of Artemis-2 Pressure vessel at Michoud Assembly Facility completed in July 2018 before being transported to the O&C at KSC*



*Artemis-2 Pressure vessel after final weld complete being moved for shipment to O&C at KSC*



*Artemis-2 Pressure vessel in assembly fixture at O&C in KSC*



# Human Exploration and Operations

## Space Launch Systems: FY 2020 Program Review

(\$M)	2019 *	2020**	2021	2022	2023	2024
<b>FY 2020 PBR</b>	<b>\$2,150.0</b>	<b>\$2,285.9</b>	<b>\$1,837.5</b>	<b>\$1,933.0</b>	<b>\$2,221.2</b>	<b>\$2,253.3</b>

\*2019 column reflects Enacted, will be updated pending Operating Plan approval

\*\*2020 column reflects adjustment for Agency Budget Amendment

- Program Plans for FY 2020

- Deliver Artemis-1 Core Stage to EGS
- Complete Artemis-1 vehicle loads analysis
- Complete SLS Block 1 design certification
- Continue manufacturing Artemis-2 and beyond SLS components
- Continue DDT&E work on Universal Stage Adaptor Payload Adaptor
- Start Artemis-3 production and initiate long lead material purchase for Artemis-4 and Artemis-5



*Intertank Structural Test Article in Test Stand at MSFC*



*Artemis-I Launch Vehicle Stage Adaptor with Thermal Protection System (TPS) application completed on May 10, 2018*

- Major Changes in FY 2020

- Modify Artemis-2 flight configuration to utilize a SLS Block 1 core stage with a human rated ICPS instead of Block 1B
- Deferred SLS Block 1B development



# Human Exploration and Operations

## Exploration Ground Systems: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
FY 2020 PBR	\$592.8	\$400.1	\$357.8	\$388.7	\$448.1	\$401.3

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

- Program Plans for FY 2020
  - Begin integrated operations
  - Build-up/stack the Integrated Launch Vehicle
  - Start construction on Emergency Egress System
- Major Changes in FY 2020
  - Increased price of propellants and commodities
  - Deferred development and completion of Second Mobile Launcher Platform



*NASA's mobile launcher (ML) atop crawler-transporter 2 begins its trek to Launch Pad 39B on Aug. 30, 2018, at the agency's Kennedy Space Center in Florida. The ML will undergo a fit check on the surface of the pad, followed by several days of systems testing*





# Human Exploration and Operations

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## International Space Station



# Human Exploration and Operations

## *International Space Station (Operations & Research): FY 2020 Program Review*

(\$M)	2019 *	2020	2021	2022	2023	2024
<b>FY 2020 PBR</b>		\$1,458.2	\$1,448.5	\$1,449.4	\$1,352.6	\$1,315.8

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

### ● Program Plans for FY 2020

- Continue to foster commercialization of LEO and ensure maximum ISS utilization
  - Implement operational cost reduction activities consistent with ISS Transition Report
  - NanoRacks: Bishop Airlock - five times the satellite deployment volume vs current Japanese Airlock capacity
- Continue leading safe and productive Human Spaceflight international partnership presence in LEO; activities including
  - USOS EVAs - 14; Russian EVAs - 6
  - USOS Crew Dockings - 3; Soyuz Docking - 1
  - USOS Resupply Dockings - 7
  - Russian Progress Dockings - 3
  - Russian Segment Module Hardware Deliveries - 1



*NASA astronaut Scott Tingle swaps out a degraded robotic hand, or Latching End Effector, on the Canadarm2 (1/23/2018)*



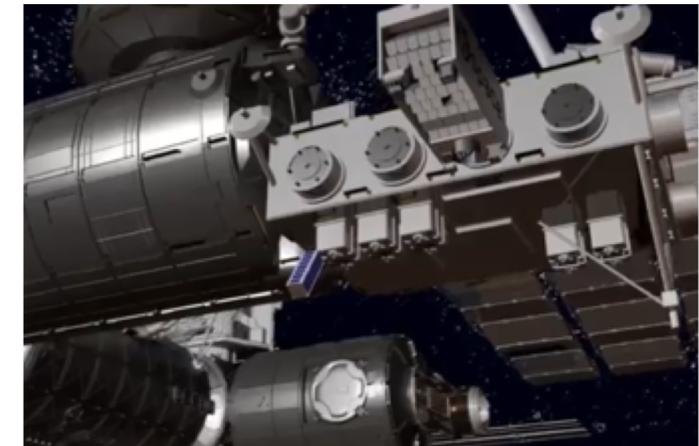
# Human Exploration and Operations

## *International Space Station (Operations & Research): FY 2020 Program Review (continued)*

- Program Plans for FY 2020 (continued)
  - Continuous effort to discover and implement efficiencies:
    - Efficiencies include content reductions, streamlining activities, contract incentives and contract consolidations
  - Perform world class science and technology demonstrations to improve life on Earth, human exploration in LEO and beyond and support activities for astrophysics, earth and space science, biological and physical sciences and private industry including:
    - Fundamental research: Cold Atom Lab (CAL) Atom Interferometry Upgrade – implementation of Atom Interferometry capability
    - Fundamental and exploration research: Flow Boiling and Condensation Experiment – begin operating the ISS Fluids rack studying larger scale two-phase fluid flows
    - Exploration Demonstration: Advanced Twin Lifting and Aerobic System–Test exercise hardware for deep space exploration (HRP)
    - Earth science: Ongoing OCO3 and Sage-III operations
- Major Changes in FY 2020
  - Reductions beginning in FY 2023 as ISS direct funding ramps down; contingent on transition to commercial capabilities



*CAL - multi-user facility designed to study ultra-cold quantum gases in the microgravity environment of the ISS*



*bSpace-ARQ: shown deploying a satellite. The facility is about the size of a motorcycle, berthed by the SPDM robotic arm, immediate video feedback provided*



# Human Exploration and Operations

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## Commercial LEO Development



# Human Exploration and Operations

## Commercial LEO Development: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
FY 2020 PBR	\$40.0	\$150.0	\$175.0	\$200.0	\$225.0	\$225.0

\*2019 column reflects Enacted, will be updated pending Operating Plan approval

### ● Program Plans for FY 2020

- Make selections for commercial module(s)/platform(s) attached to ISS and free-flying for commercial development of LEO destinations
- Seek out and pursue opportunities to stimulate sustainable demand and catalyze new markets that will enable a space economy in LEO in which NASA is one of many customers
- Partner with industry to establish and grow new markets through use of ISS for commercial activities as enabled by new NASA Interim Directive on commercial use of ISS
- Enable private astronaut missions to ISS

### ● Major Changes in FY 2020

- None





# Human Exploration and Operations

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## Space Transportation

*Crew and Cargo Program*  
*Commercial Crew Program*



# Human Exploration and Operations

## Crew and Cargo Program: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
FY 2020 PBR		\$1,726.6	\$1,789.6	\$1,751.2	\$1,683.0	\$1,662.5

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

### ● Program Plans for FY 2020

#### ➤ Cargo Transportation

- Northrop Grumman has two flights planned under CRS-2
  - As a example, after departing from, ISS NG-11 will demonstrate its capability to fly solo for up to a year, as a free-flying laboratory for science experiments, technology demonstrations and as a CubeSat launch platform
- SpaceX has two flights planned under CRS-1 and one flight planned under CRS-2
- Sierra Nevada has one flight planned under CRS-2

#### ➤ Crew Transportation

- ISS is expecting one Boeing mission and one SpaceX commercial crew mission per year once the providers are flying regularly

### ● Major Changes in FY 2020

- Reductions beginning in FY 2023 as ISS direct funding ramps down; contingent on transition to commercial capabilities



*The Northrop Grumman Cygnus spacecraft is pictured approaching its capture point (11/14/2017)*



# Human Exploration and Operations

## Commercial Crew Program: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
<b>FY 2020 PBR</b>		<b>\$102.0</b>	<b>\$64.5</b>	<b>\$63.2</b>	<b>\$63.2</b>	<b>\$64.6</b>

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

- Program Plans for FY 2020

- Certify crew transportation systems after successful completion of their flight test without and with crew
- Fly PCMs to meet ISS crew rotation and emergency return obligations
- Transition to sustaining operations at a level needed to safely operate with two commercial providers
- Continue to manage CCtCap contracts, including providing technical oversight and managing modifications and upgrades to the transportation systems



*SpaceX Falcon 9 rocket lifts off from Launch Complex 39A at NASA's Kennedy Space Center in Florida for Demo-1, the first uncrewed mission of the Commercial Crew Program. (March 2019)*



# Human Exploration and Operations

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## Space Flight Support

*Space Communications and Navigation Program*

*Communication Services Program*

*Rocket Propulsion Testing Program*

*Launch Services Program*

*Human Space Flight Operations*



# Human Exploration and Operations

## *Space Communications and Navigation: FY 2020 Program Review*

<b>(\$M)</b>	<b>2019 *</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>	<b>2024</b>
<b>FY 2020 PBR</b>		<b>\$611.0</b>	<b>\$632.4</b>	<b>\$593.0</b>	<b>\$562.9</b>	<b>\$557.0</b>

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

- Program Plans for FY 2020

- Maintain high proficiency levels for all three networks
- Complete Deep Space Station (DSS)-56 installation, integration and test activities and continue activities toward completion of DSS-53 for FY 2021 operations
- Mature Deep Space Optical Communications and Navigation and develop necessary ground and space infrastructure
- Complete final Space Network Ground Segment Sustainment (SGSS) milestones required to achieve Final Acceptance Review, including Level 5 test completion at White Sands Complex



# Human Exploration and Operations

## *Space Communication and Navigation: FY 2020 Program Review (continued)*

- Major Changes in FY 2020
  - Transfer Next Generation Capability project to Communication Services Program
  - Redesign optical payload to reduce mass on Orion
    - Provide higher data rates which will significantly improve the crew's ability to connect with NASA and society as a whole while in space
    - Allow for high-definition (HD) images and streaming video (80 Mbps+) during flight which would otherwise not be available with existing Radio Frequency technology
    - Provide continuous and detailed flight data which will significantly increase our ability to analyze flights and make informed decisions on future flights
  - Laser Communications Relay Demonstration launch schedule delayed as a result of host spacecraft delays, launch is currently scheduled for August 2020
  - ILLUMA T manifested to launch in FY 2022



# Human Exploration and Operations

## Communication Services Program: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
<b>FY 2020 PBR</b>		<b>\$3.0</b>	<b>\$23.4</b>	<b>\$67.0</b>	<b>\$101.2</b>	<b>\$108.9</b>

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

- Communication Services Program is being established to
  - Demonstrate the feasibility of commercially provided data relaying services
  - Pursue opportunities that will allow future NASA missions to deploy flight qualified capabilities for near-Earth missions to get support from commercial providers
  - Support the management, engineering, and acquisition functions required to develop an initial pilot acquisition vehicle for commercial communications services, and begin formulating a future communications architecture based on these services
    - Pursue public-private partnerships to further commercialize low Earth orbit
  - Work with commercial markets to identify requirements and explore opportunities that are mutually beneficial to NASA and industry
- Program Plans for FY 2020
  - Support management, engineering and acquisition functions required to establish program
  - Develop initial pilot acquisition vehicle for commercial communications services
  - Begin formulating future communications architecture based on these services



*An illustration of future commercially provided data relay services*



# Human Exploration and Operations

## Rocket Propulsion Test: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
<b>FY 2020 PBR</b>		<b>\$46.5</b>	<b>\$47.6</b>	<b>\$47.6</b>	<b>\$47.6</b>	<b>\$47.6</b>

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

- Program Plans for FY 2020

- Stennis Space Center

- Continue testing SLS RS-25 engines on A-1 test stand
- Continue Aerojet Rocketdyne RS-68 engine testing for the Delta IV launch vehicle on B-1 test stand (industry-funded SAA)
- Continue testing Nuclear Thermal Propulsion Subscale Exhaust Capture System (Exploration Technology)

- Glenn Research Center Plum Brook Station

- Complete modifications of the In-Space Propulsion Facility (ISPF)
- Begin testing Northrop Grumman upper stage for OmegA launch system (industry-funded SAA)

- White Sands Test Facility

- Continue testing for Orion ESA Service Module and Boeing CST-100 Service Module
- Provide critical propulsion test services to Missile Defense Agency, Aerojet Rocketdyne and US Air Force test articles

- Marshall Space Flight Center

- Provide test capabilities for research and development oriented test campaigns, such as additive manufactured components



# Human Exploration and Operations

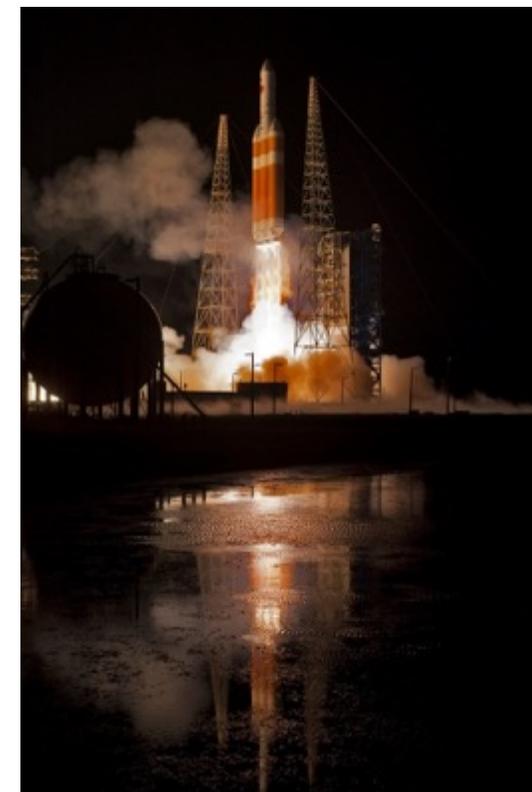
## Launch Services: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
FY 2020 PBR		\$88.6	\$88.6	\$88.6	\$88.6	\$88.6

*\*2019 column reflects Enacted, will be updated pending Operating Plan approval*

- Program Plans for FY 2020

- Continue mission design and launch integration support to over 60 missions in various stages of development
- Successfully launch:
  - Solar Orbiter, scheduled for February 2020
  - Mars 2020, scheduled for July 2020
  - Landsat 9, scheduled for December 2020
- Certify new commercial launch vehicles to launch high-value civil-sector payloads
- Provide commercial logistics acquisition services for Artemis



*At Cape Canaveral Air Force Station's Space Launch Complex 37, the United Launch Alliance Delta IV Heavy rocket with NASA's Parker Solar Probe, lifts off at 3:31 a.m. EDT on Sunday, Aug. 12, 2018*



# Human Exploration and Operations

## Human Space Flight Operations: FY 2020 Program Review

(\$M)	2019 *	2020	2021	2022	2023	2024
FY 2020 PBR		\$99.8	\$99.9	\$109.5	\$111.4	\$112.4

\*2019 column reflects Enacted, will be updated pending Operating Plan approval

- Program Plans for FY 2020

- Maintain Astronaut Occupational Health program that includes clinical certification for active astronauts, health and fitness through training, flight and post mission recovery
- Continue development of a lifetime astronaut occupational surveillance program to provide healthcare for former astronauts and enhanced long term health monitoring, in support of the TREAT Astronauts Act
- Provide trained astronauts for NASA human space flight efforts, direct and manage flight crew activities, select astronaut candidates for future space flight missions
- Operate program support aircraft for space flight readiness training and direct crew return and Super Guppy for transporting oversized cargo

- Major Changes from FY 2019 PBR

- Transfer Aerosciences to Safety, Security and Mission Services account



*The astronauts assigned to crew the first flight tests and missions of the Boeing CST-100 Starliner and SpaceX Crew Dragon*

An astronaut in a white space suit is shown from the chest up, floating in space. The astronaut's helmet is prominent, reflecting the bright red surface of Mars. The background features a large, detailed view of the Moon's surface with numerous craters, and a smaller view of the Earth in the distance. The overall scene is set against a dark, star-filled sky.

# EXPLORE MOON *to* MARS

MOON LIGHTS THE WAY



# Human Exploration and Operations

## *Acronym List*

AA	Ascent Abort	LEO	low Earth orbit
ACSC	Advanced Cislunar and Surface Capabilities	LVSA	Launch Vehicle Stage Adapter
BAA	Broad Area Announcement	MAF	Michoud Assembly Facility
CAL	Cold Atom Lab	MSFC	Marshall Space Flight Center
CATALYST	Cargo Transportation And Landing bY Soft Touchdown	NASA	National Aeronautics and Space Administration
CCP	Commercial Crew Program	NextSTEP	Next Space Technologies for Exploration Partnerships
CCtCap	Commercial Crew transportation Capability	NG	Northrop Grumman
CLPS	Commercial Lunar Payload Services	NIH	National Institutes of Health
CLV	Commercial Launch Vehicle	NRHO	Near Rectilinear Halo Orbit
CM	Crew Module	OCO	Orbital Carbon Observatory
CMA	Crew Module Adapter	OSA	Orion Stage Adapter
CRS	Commercial Resupply Services	PCM	Post Certification Mission
DDT&E	Design Development Test and Evaluation	PPE	Power and Propulsion Element
DoD	Department of Defense	RFI	Request For Information
DSS	Deep Space Station	RPT	Rocket Propulsion Test
EGS	Exploration Ground Systems	Saffire	Spacecraft Fire Experiment
ESA	European Space Agency	SGSS	Space Network Ground Segment Sustainment
ESM	European Service Module	SLS	Space Launch System
EUS	Exploration Upper Stage	SM	Service Module
EVA	Extravehicular Activity	SMD	Science Mission Directorate
HEO	Human Exploration and Operations Mission Directorate	SpaceX	Space Exploration Technologies Corporation
HRP	Human Research Program	STA	Structural Test Article
ICESat-2	Ice, Clouds, and land Elevation Satellite	STMD	Space Technology Mission Directorate
ICPS	Interim Cryogenic Propulsion Stage	TESS	Transiting Exoplanet Survey Satellite
InSight	Interior Exploration using Seismic Investigations, Geodesy and Heat Transport	TREAT	“To Research, Evaluate, Assess, and Treat” Astronauts Act
ISS	International Space Station	URT-7	Underway Recovery Test-7
JSC	Johnson Space Center	USOS	U.S. Orbital Segment
KPLO	Korea Pathfinder Lunar Orbiter	UWMS	Universal Waste Management System
KSC	Kennedy Space Center	VAB	Vehicle Assembly Building